Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/GB2008/051040

International filing date: 07 November 2008 (07.11.2008)

Document type: Certified copy of priority document

Document details: Country/Office: GB
Number: 0805791.1
Filing date: 31 March 2008 (31.03.2008)

Date of receipt at the International Bureau: 19 December 2008 (19.12.2008)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)

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AN IMPROVED MIST GENERATING APPARATUS

The present invention is directed to the field of mist generating apparatus, which generate and spray a mist of droplets. The apparatus of the present invention is particularly, although not exclusively, suited for use in cooling, fire suppression and decontamination applications.

Mist generating apparatus are known which inject a high-velocity transport fluid into a working fluid in order to atomise the working fluid and form a dispersed droplet-vapour flow regime which is then sprayed into the atmosphere. Examples of such apparatus can be seen in WO2005/082545 and WO2005/082546 to the same applicant. In the apparatus disclosed in these publications, a transport fluid is injected at high velocity into the working fluid and the working fluid is sprayed from a nozzle in a single general direction. When only sprayed in a single direction, the spray pattern of the droplets will have limited coverage, or else take longer to fill a given volume. As a result, when used in an application to suppress a fire in a room, for example, a number of mist generating apparatus of this type will be needed to ensure coverage of the entire room.

It is an aim of the present invention to obviate or mitigate the aforementioned disadvantage.

According to a first aspect of the present invention, there is provided a mist generating apparatus, comprising:

a first working fluid passage in fluid communication with a first working fluid inlet and a first working fluid outlet;

a transport fluid passage in fluid communication with a supply of transport fluid; and

a transport fluid nozzle in fluid communication with the transport fluid passage, the nozzle having a nozzle inlet, a nozzle outlet, and a throat portion intermediate the nozzle inlet and nozzle outlet, the throat portion having a smaller cross-sectional area than the nozzle inlet and outlet;

wherein the first working fluid outlet is located adjacent the nozzle outlet such that a mist is formed as a stream of working fluid issuing from the working fluid outlet is atomised by a stream of transport fluid issuing from the nozzle outlet;

and wherein the first working fluid outlet and the nozzle outlet each extend around at least a portion of the perimeter of the apparatus such that the mist is sprayed over an angle of substantially 90 degrees or more.

Preferably, the first working fluid outlet and the nozzle outlet each extend around the entire perimeter of the apparatus such that the mist is sprayed over an angle of substantially 360 degrees.

Preferably, the first working fluid outlet and the nozzle outlet each extend continuously around at least a portion of the perimeter of the apparatus.

Alternatively, the first working fluid outlet and the nozzle outlet each extend discontinuously around at least a portion of the perimeter of the apparatus such that the apparatus comprises a plurality of first working fluid outlets and nozzle outlets.

Preferably, the apparatus further comprises a first member having a longitudinally extending bore therethrough, and a first flange projecting radially outwardly from a first end thereof, wherein the first working fluid inlet and first working fluid passage are located in the first member, and

the first working fluid outlet is located on a first outer surface of the first flange.

Preferably, the apparatus further comprises a second member having a longitudinally extending shaft and a second flange projecting radially outwardly from an end of the shaft, wherein the shaft is located in the bore of the first member such that the transport fluid passage is defined between the shaft and the wall of the bore, and the transport fluid nozzle is defined between a second outer surface of the second flange and the first outer surface of the first flange.

Preferably, the apparatus further comprises a second working fluid passage in fluid communication with a second working fluid inlet and a second working fluid outlet, wherein the first and second working fluid outlets are located adjacent the nozzle outlet such that a mist is formed as streams of working fluid issuing from the working fluid outlets are atomised by a stream of transport fluid issuing from the nozzle outlet, and wherein the second working fluid outlet extends around at least a portion of the perimeter of the apparatus such that the mist is sprayed over an angle of substantially 90 degrees or more.

Preferably, the second working fluid outlet extends around the entire perimeter of the apparatus such that the mist is sprayed over an angle of substantially 360 degrees.

Preferably, the second working fluid outlet extends continuously around at least a portion of the perimeter of the apparatus.

Alternatively, the second working fluid outlet extends discontinuously around at least a portion of the perimeter of the apparatus such that the apparatus comprises a plurality of second working fluid outlets.

Preferably, the second working fluid inlet and the second working fluid passage are located in the second member, and the second working fluid outlet is located on the second outer surface of the second flange.

Preferably, the first and second working fluid passages extend radially outwardly within the first and second flanges. Preferably, the first working fluid outlet extends around the first member. Preferably, the second working fluid outlet extends around the second member.

Preferably, the second member is adjustable relative to the first member, such that the distance between the first and second outer surfaces of the first and second flanges can be varied. Thus, the cross-sectional area of the transport fluid nozzle and the area ratio between the nozzle throat and nozzle outlet can be varied.

In one preferred embodiment, both the first and second flanges include an inner working fluid outlet and an outer working fluid outlet located radially outwardly of the inner working fluid outlet.

In an alternative preferred embodiment, the first flange includes an inner working fluid outlet and an outer working fluid outlet located radially outwardly of the inner working fluid outlet.

Preferably, both inner and outer outlets extend around at least a portion of the perimeter of the first flange.

Preferably, the inner and outer working fluid outlets each extend around the entire perimeter of the first flange.

Preferably, the inner and outer working fluid outlets each extend continuously around at least a portion of the perimeter of the first flange.

Alternatively, the inner and outer working fluid outlets each extend discontinuously around at least a portion of the perimeter of the first flange such that the apparatus comprises a plurality of inner and outer working fluid outlets.

Preferably, one or both of the first and second outer surfaces of the first and second flanges includes protrusions and/or indentations to enhance flow turbulence between the first and second outer surfaces.

Preferably, one or more of the working fluid outlets is provided with a working fluid nozzle, wherein the angle of the working fluid nozzle can be adjusted relative to the first and second outer surfaces. Thus, the angle at which the working fluid streams encounter the transport fluid can be varied.

Where the working fluid outlet and nozzle outlet extend continuously around the perimeter of the apparatus, the apparatus preferably further comprises blocking means which may be located between the first and second outer surfaces to selectively block a portion of the working fluid outlets and the transport fluid nozzle outlet. In doing so, the blocking means can adapt the apparatus such that it sprays the mist over only a portion of the area covered by the apparatus.

Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows a vertical section through a first embodiment of a mist generating apparatus;

Figure 2 shows a vertical section through a second embodiment of a mist generating apparatus;

Figure 3 shows a vertical section through a third embodiment of a mist generating apparatus;

Figure 4 shows a vertical section through a fourth embodiment of a mist generating apparatus; and

Figure 5 shows a perspective view of the embodiment of the mist generating apparatus shown in Figure 4.

Figure 1 shows a first embodiment of a mist generating apparatus, generally designated 100. The apparatus is adapted to produce a substantially annular mist or spray pattern of atomised droplets over an angle of substantially 360 degrees, and comprises a first member 101 and a second member 102.

The first member 101 has a generally cylindrical body 114 which has a first end connected to a supply of working fluid (not shown) and a second end having a first flange, or disc, 112 projecting radially outwardly therefrom. The body 114 defines a first working fluid inlet 130 which is in fluid communication with the working fluid supply. The body 114 also includes a central bore 118, which extends through the body 114 in a direction generally parallel with the first working fluid inlet 130. The first disc 112 defines a first working fluid passage 132 which is generally perpendicular to, and in fluid communication with, the first working fluid inlet 130. A first working fluid outlet 160 is provided at the remote end of

the first working fluid passage 132 so that working fluid may pass from the first working fluid passage 132 through the outer surface 140 of the first disc 112. The first working fluid outlet 160 has a reduced cross-sectional area compared to the first working fluid passage 132. In the illustrated embodiment, both the first working fluid passage 132 and first working fluid outlet 160 extend about the entire perimeter of the first disc 112, such that both the passage 132 and outlet 160 form annuli about the first member 101.

The second member 102 has a longitudinally extending shaft 124 having a first end connected to a supply of working fluid (not shown) and a second end having a second flange, or disc 122, projecting radially outwardly therefrom. During assembly, the shaft 124 is received in the bore 118 such that the wall 119 of the bore 118 and shaft 124 define a transport fluid passage 128 between them.

The shaft 124 has a second working fluid inlet 134 which is connected to a working fluid supply. The second working fluid inlet 134 is generally parallel to the first working fluid inlet 130 and the transport fluid passage 128. The second disc 122 defines a second working fluid passage 136 which is generally perpendicular to, and in fluid communication with, the second working fluid inlet 134. A second working fluid outlet 170 is provided at the remote end of the second working fluid passage 136 so that working fluid may pass from the second working fluid passage 136 through the outer surface 142 of the second disc 122. The second working fluid outlet 170 has a reduced cross-sectional area compared to the second working fluid passage 136. The second working fluid outlet 170 is oriented such that working fluid will pass out of the outlet in the general direction of the first disc 112 and first working fluid outlet 160. In the illustrated embodiment, both the second working fluid passage 136

and second working fluid outlet 170 extend about the entire perimeter of the second disc 122, such that the outlet 170 forms an annulus about the second member 102.

With the shaft 124 inserted into the bore 118 of the first member 101, the first and second discs 112,122 are brought into close proximity. With the first and second discs 112,122 close to one another, their respective outer surfaces 140,142 define a nozzle 150 having a convergent-divergent inner geometry. By convergent-divergent geometry, it is meant that the nozzle 150 has a nozzle inlet 151 and a nozzle outlet 155, and a throat portion 153 intermediate the nozzle inlet 151 and nozzle outlet 155 which has a reduced cross-sectional area when compared with that of the inlet 151 and outlet 155. The nozzle 150 is in fluid communication with the transport fluid passage 128 to receive transport fluid therefrom. As with the first and second working fluid passages 132,136 and the transport fluid passage 128, the nozzle 150 outlet extends around the entire perimeter of the apparatus 100. Consequently, the nozzle outlet forms an annulus.

It is preferable that the position of the second member 102 can be adjusted relative to the first member 101, and that this is achieved by varying the extent to which the shaft 124 is axially inserted into the bore 118. This adjustment varies the distance between the outer surfaces 140,142 of the discs 112,122, and consequently the internal geometry of the nozzle 150 can be adjusted to vary the atomisation of the working fluid by the transport fluid.

The method of operation of the apparatus shown in Figure 1 will now be described. Initially, a working fluid - preferably water - is supplied from a working fluid supply to the first and second working fluid inlets 130,134. The respective inlets 130,134 may receive working fluid from the same

supply, or else separate supplies can be used for each inlet 130,134. The working fluid will pass from the inlets 130,134 into the first and second working fluid passages 132,136, and from there to the respective working fluid outlets 160,170. As the outlets 160,170 are preferably of a reduced cross-sectional area compared to their respective working fluid passages 160,170, there is a build up of pressure in the working fluid passages 132,136. This leads to a stream of working fluid spraying out through the outlets 160,170.

A transport fluid – preferably steam - is supplied to the transport fluid passage 128 from a transport fluid supply, and will then pass through the transport fluid nozzle 150. As the transport fluid passes through the convergent-divergent geometry created by the nozzle inlet 151, throat portion 153 and nozzle outlet 155, it undergoes an acceleration which causes the transport fluid to leave the nozzle outlet 155 at very high - and in some instances supersonic – velocity.

As the high velocity transport fluid leaves the nozzle outlet 155, it comes into contact with the streams of working fluid exiting the working fluid outlets 160,170 adjacent the nozzle outlet 155. As the two fluids come into contact an energy transfer takes place between the two, primarily as a result of mass and momentum transfer between the high velocity transport fluid and the relatively low velocity working fluid. In the case where steam is the transport fluid, heat transfer between the high temperature transport fluid and lower temperature working fluid also forms part of the energy transfer between the two fluids. This energy transfer imparts a shearing force on the working fluid streams, leading to the atomisation of the working fluid streams. This atomisation leads to the creation of a dispersed droplet-vapour flow regime exiting the apparatus 100 over a 360 degree angle as a mist. By varying the relative positions of the first and

second members 101,102, and consequently the distance between the surfaces 140,142, the velocity of the transport fluid can be varied such that the degree of atomisation of the working fluid can also be varied accordingly.

The atomisation of the working fluid is achieved using primary and secondary break-up mechanisms. The primary mechanism is the high shear force applied to the working fluid by the transport fluid, which forms ligaments at the boundary surface of the water. These ligaments are stripped from the surface and atomised into droplets. Two secondary break-up mechanisms further atomise the working fluid droplets produced by the primary break-up. These secondary mechanisms are a further shear force caused by the remaining differential between the relative velocities of the transport and working fluid streams, and the turbulent eddy break-up of the working fluid caused by the turbulent flow of the transport fluid.

As the working fluid and transport fluid passages 132,136,128, the working fluid outlets160,170, and the nozzle 150 extend about the entire perimeter of the apparatus 100, the mist sprayed from the apparatus exits the apparatus in an annular, 360 degree, stream. Thus, the apparatus 100 sprays the mist over an angle of substantially 360 degrees, allowing improved coverage of an area when compared to existing mist generating apparatus which only spray in a single general direction.

The working fluid outlets 160,170 of the first embodiment of the present invention are shown in Figure 1 to both be angled to direct their respective streams of working fluid downstream and away from the nozzle outlet 155. In this manner, the streams will collide and disrupt one another. This disruption of the working fluid streams augments and further improves the

atomisation of the working fluid caused by the transport fluid exiting the nozzle outlet 155.

Alternative arrangements of the working fluid outlets can also be incorporated into the present invention to further improve atomisation performance. A second preferred embodiment of the apparatus is shown in Figure 2, and is generally designated 100'. The second embodiment includes one such alternative arrangement in which the first and second working fluid passages 132',136' each have a respective inner working fluid outlet 160a,170a and outer working fluid outlet 160b,170b. The inner and outer outlets form concentric annuli about the first and second discs 112,122. As with the first embodiment, the pair of inner outlets 160a,170a and the pair of outer outlets 160b,170b are angled to direct their respective streams of working fluid downstream and away from the nozzle outlet 155'. In this manner, the streams from the inner outlets 160a,170a will collide and disrupt one another, as will the streams from the outer outlets 160b,170b. The arrangement of the second embodiment further improves the disruption of the working fluid streams that augments and further improves the atomisation of the working fluid by the transport fluid.

In Figure 3, a third embodiment of the apparatus, generally designated 100", is shown which employs a further alternative arrangement of working fluid outlets. This third embodiment is effectively a combination of components from the first and second embodiments, combining a first member 101" of the type used in the second embodiment with a second member 102" of the type used in the first embodiment. As a result, the first working fluid passage 132" has inner and outer working fluid outlets 160a,160b as with the second embodiment, but the second working fluid passage 136" located in the second member 102" has only a single working fluid outlet 170 as with the first embodiment. The working fluid

outlets 160a,160b of the first member 101" and the working fluid outlet 170 of the second member 102" are positioned on their respective members such that they are staggered, or offset. In other words, the working fluid outlet 170 is positioned such that its annulus lies between those of the inner and outer working fluid outlets 160a,160b relative to the transport fluid nozzle 150". In this third embodiment, the working fluid streams issuing from the outlets 160a,160b,170 do not directly collide with one another, but instead create a degree of turbulence which disrupts each working fluid stream to further enhance the atomisation of the working fluid achieved by the transport fluid.

The outer surfaces 140,142 of the discs 112,122, which define the transport fluid nozzle 150, can include protrusions or indentations to further enhance the turbulence as the transport fluid atomises the working fluid. Such a modification could be made to any of the three embodiments described above.

Whilst the illustrated first, second and third embodiments of the present invention all employ a second working fluid passage and second working fluid outlet(s) in the second member, it should be understood that the apparatus may also operate successfully with only the first working fluid passage and outlets in the first member. In such an instance, the second outer surface of the second disc would still assist in defining the transport fluid nozzle, but no working fluid would be sprayed from the second disc. However, for optimum atomisation of the working fluid, it is preferable for there to be first and second working fluid passage and outlets in the respective first and second discs.

The nozzle outlets, the first working fluid outlet of the first embodiment and the inner and outer outlets of the second and third embodiments are

described in the embodiments above as being annular and extending about the entire perimeter of the apparatus. However, it should be appreciated that one or more of the nozzle outlets, the first working fluid outlets and the inner and outer outlets may instead extend around only a portion of the apparatus such that a mist is sprayed over an angle of substantially 90 degrees or more. The same may apply to the second working fluid outlet.

Furthermore, one or more of the nozzle outlets, the first and second working fluid outlets and inner and outer outlets may extend discontinuously around the perimeter of the apparatus, either over a portion of the perimeter or the entire perimeter. Consequently, the apparatus may comprise a plurality of one or more of the nozzle outlets, first and second working fluid outlets and inner and outer outlets.

The plurality of first working fluid outlets are each in fluid communication with a single first working fluid passage. Alternatively, the first disc can include a corresponding plurality of first working fluid passages, each of which is in fluid communication with a respective one of the plurality of first working fluid outlets.

The plurality of second working fluid outlets are each in fluid communication with a single second working fluid passage. Alternatively, the second disc can include a corresponding plurality of second working fluid passages, each of which is in fluid communication with a respective one of the plurality of second working fluid outlets.

Furthermore, the angle of each working fluid outlet and inner and outer outlet and its configuration (e.g. area ratio and associated included angle) can be adapted to provide a mist with desired properties. These

adjustments are preferably made during manufacture of the apparatus. However, the working fluid outlets can be provided with directional working fluid nozzles which can be adjusted to vary the angle at which the working fluid stream encounters the transport fluid.

Whilst the transport fluid nozzle preferably produces a substantially annular mist, it may be desirable to block selective portions of the nozzle by way of a blocking means. For example, if locating a mist generating apparatus of the present invention in the corner of a room, a blocking portion may be inserted between the first and second outer surfaces to block the working fluid outlets and the transport fluid nozzle outlet. This ensures that all of the mist is sprayed out into the room and none of the mist is wasted by being sprayed directly into the corner.

Whilst the inlets, passages, outlets and nozzles of the foregoing embodiments have been described as handling working fluid or transport fluid, it should be appreciated that the apparatus can be reconfigured to reverse the layout described herein. In other words, the working fluid inlets, passages and outlets could be used to handle transport fluid, whilst the transport fluid inlets, passages and nozzle could be used to handle working fluid. In such a case, what are currently the working fluid passages would need to be modified to provide a convergent-divergent internal geometry so as to accelerate the transport fluid to the appropriate velocity to atomise the working fluid.

In the foregoing embodiments, the transport fluid used is steam. However, it should be understood that other fluids may be used instead. For example, a compressed gas such as air or nitrogen could be used in place of steam.

A fourth embodiment of a mist generating apparatus according to the present invention is shown in Figures 4 and 5 and generally designated 200. The apparatus 200 has a longitudinal axis L and comprises a generally cylindrical body 202 having a primary passage 204 defined therein. The passage 204 extends longitudinally through the entire body 202 and is co-axial with the longitudinal axis L of the apparatus 200. The body has a first end 206 and a second end 208, and the passage 204 has an inlet 210 and an outlet 212 at the respective first and second ends 206,208 of the body 202. A portion of the passage 204 adjacent the first end 206 has an inner thread 214. A groove 218 is also provided in the outer surface of the body 202 adjacent the second end 208. Within the groove 218 is located an O-ring seal 220.

The body 202 includes a flange portion 222 which adjoins the second end 208 and which projects radially from the longitudinal axis L. The flange portion 222 defines an abutment face 224 facing towards the second end 208 and a nozzle gap defining face 226 facing away from the second end 208. The outer surface of the flange portion 222 is provided with a threaded portion 216. The body 202 also includes a section 228 having an increased diameter compared to the remainder of the body 202. The increased diameter section 228 is located intermediate the first and second ends 206,208 of the body 202. Defined within the increased diameter section 228 are a number of secondary passages 230 which are substantially parallel to the primary passage 204 and are equidistantly spaced about the circumference of the body 202. The increased diameter section 228 has an external surface 232 in which two grooves 234,236 are defined, the grooves 234,236 being longitudinally spaced from one another. The grooves 234,236 each contain a respective O-ring seal 238,240. A free space 242 is defined between the increased diameter section 228 and the flange portion 222.

The apparatus 200 also includes a generally circular disc member 250. The disc 250 has a front face 252, a rear face 254, and a central aperture. The aperture has a smaller diameter portion 256 adjacent the front face 252 and a larger diameter portion 258 adjacent the rear face 254. The internal surface of the larger diameter portion 258 is threaded. The rear face 254 of the disc 250 has a first annular channel 260 extending around the central aperture. A plurality of small passages 262 extend through the disc 250 from the annular channel 260 to the front face 252. The passages 262 are equidistantly spaced about the disc 250 such that they surround the central aperture. Located in the annular channel 260 is an annular insert 261 formed from a material having good machining properties. In this preferred example, the insert 261 is made from brass. The insert 261 is fixed in the channel 260 by a number of threaded fixtures (not shown) which pass though holes provided in the disc 250 into threaded holes in the insert 261. When fixed in the channel 260, the insert 261 defines a first annular working fluid nozzle 263 opening onto the rear face 254 of the disc 250. The nozzle 263 is in fluid communication with the passages 262 such that fluid communication is possible between the front and rear faces 252,254 of the disc 250.

Spaced about the circumference of the disc 250 are a number of threaded adjustment apertures 264. Located in each adjustment aperture 264 is a threaded adjuster 266. One end of each adjuster 266 projects from the front face 252 of the disc 250, and is adapted to receive an adjustment tool (not shown). The other end of each adjuster 266 projects from the rear face 254 of the disc 250. A number of threaded fixing apertures 268 are also provided in the disc 250 for receiving fixing means, as will be described in more detail below.

The apparatus 200 also comprises a cap member 270. The cap 270 has an outer face 272 and an inner face 274. The outer face 272 has a number of apertures 276 which extend longitudinally through the cap 270 and which receive fixtures 278 therein. The inner face 274 has an annular channel 280 which surrounds the centre and longitudinal axis L of the cap 270. Also formed in the inner face 274 is an annular groove 282, within which is located an O-ring seal 284, and also a number of cavities 286 adapted to receive the heads of the threaded adjusters 266 in the disc 250, as will be described below.

The apparatus 200 also includes a ring member 290 having a front face 292 and a rear face 294 and a central aperture. Extending axially from the rear face 294 is an annular lip 298. The lip 298 has an inner surface 300 which defines the central aperture, and an outer surface 302. Formed in the front face 292 of the ring 290 is a second annular channel 304 extending around the central aperture of the ring 290. A plurality of small passages 306 extend through the ring 290 from the annular channel 304 to the rear face 294. The passages 306 are equidistantly spaced about the ring 290 such that they surround the central aperture. Located in the annular channel 304 is a second annular insert 308 which, as with the first annular insert 261, is formed from a material having good machining properties. In this preferred example, the insert 308 is also made from brass. The ring 290 has a number of apertures 307 extending through it. Threaded fixtures 309 pass through the apertures 307 into threaded holes in the insert 308 to fix the insert 308 in position in the channel 304. When located in the channel 304, the insert 308 defines a second annular working fluid nozzle 310 opening onto the front face 292 of the ring 290. The nozzle 310 is in fluid communication with the passages 306 such that fluid communication is possible between the front and rear faces 292,294 of the ring 290.

The penultimate component of the apparatus 200 is a cover member 320 having a first end 322 and a second end 324. The cover 320 is a generally cylindrical member having a passage 326 extending longitudinally therethrough. The passage 326 has a smaller diameter section 328 adjacent the first end 322 and a larger diameter section 330 adjacent the second end 324. Between them, the smaller diameter section 328 and the larger diameter section 330 of the passage 326 define an abutment face 332 facing in the direction of the second end 324. An annular groove 334 is provided in the second end 324 of the cover 320, in which an O-ring seal 336 is located. A pair of first supply passages 338 are provided diametrically opposite one another adjacent the first end 322 of the cover 320. The supply passages 338 are substantially perpendicular to the longitudinal axis L and allow fluid communication between the exterior of the cover 320 and the smaller diameter section 328 of the passage 326. A pair of second supply passages 340 are provided diametrically opposite one another adjacent the second end 324 of the cover 320. The supply passages 340 are also substantially perpendicular to the longitudinal axis L and allow fluid communication between the exterior of the cover 320 and the larger diameter section 330 of the passage 326.

The final component of the apparatus is a base member 350. The base 350 is generally circular and has a front face 352 and a rear face 354. A central passage 356 extends longitudinally through the base 350 and is co-axial with the longitudinal axis L. Projecting axially from the front face 352 is an annular front lip 358 which is co-axial with the passage 356. Formed in the front face 352 is an annular groove 353 in which is located an O-ring seal 355. The outer surface 360 of the front lip 358 is threaded. Projecting axially from the rear face 354 of the base 350, in the opposite

direction from the front lip 358, is a rear lip 362. The rear lip 362 is also annular and co-axial with the passage 356.

The manner in which the various components of the apparatus 200 are assembled will now be described. As described above, the first annular insert 261 is fixed into the first annular channel 260 in the disc member 250 by a number of fixtures (not shown). Between them, the insert 261 and channel 260 define a first working fluid nozzle 263. Once fixed in position, the insert 261 is machined so that the exposed surface of the insert 261 is flush with the rear face 254 of the disc 250. An identical procedure takes place in respect of the ring member 290, wherein the second insert 308 is fixed in the second channel 304 by fixtures 309 so as to define a second working fluid nozzle 310. As with the first insert 261, the second insert 308 is then machined so that the exposed surface of the insert 308 is flush with the front face 292 of the ring 290.

Once the inserts 261,308 have been machined, the disc 250 is threaded onto the flange portion 222 of the body 202 by way of their respective threaded portions 258 and 216 co-operating with one another. The disc 250 is threaded onto the body 202 until it comes into contact with the abutment face 224 of the flange portion 222. At the same time, the O-ring seal 220 ensures a sealing fit between the two components.

Following the assembly of the disc 250 to the second end 208 of the body 202, the ring member 290 is slid axially over the body 202 from the first end 206 such that the inner surface 300 of the ring 290 lies against the external surface 232 of the body 202. The O-ring seal 240 ensures a sealing fit between the ring 290 and body 202. The ring 290 slides over the body until its front face 292 comes into contact with the adjusters 266 projecting from the rear face 254 of the disc 250. Once contact is made

with the adjusters 266, the front face 292 of the ring 290 and the rear face 254 of the disc 250 define a transport fluid nozzle gap 370 between them. The thickness of both the disc 250 and ring 290 reduces in the radial direction. As a result, the nozzle gap has a diverging profile, where the cross sectional area of the nozzle gap 370 is greater at a point radially outward of the inserts 261,308 than at any point radially inward of the inserts 261,308. The nozzle gap 370 extends about the entire circumference of the apparatus 200, so as to give a full 360° range. The respective annular working fluid nozzles 263,310 of the disc 250 and the ring 290 open into the transport fluid nozzle gap 370 approximately half way along the nozzle gap 370.

Once the ring 290 is in contact with the adjusters 266, the cover 320 can be slid onto the body 202 behind the ring 290. The cover 320 slides onto the body 202 with the external surface 232 of the body 202 acting as a guide surface for the internal surface of the cover 320 defined by the smaller diameter portion 328 of the passage 326. The cover 320 slides onto the body 202 until the abutment face 332 of the cover abuts the rear of the lip 298 extending rearwards from the ring 290. At the same time, the second end 324 of the cover 320 abuts the rear face 294 of the ring 290. Once in this position, the O-ring seals 238, 336 ensure a sealing fit between the cover 320 and the body 202, and the cover 320 and the ring 290, respectively.

In order to secure all the components in place, the base member 350 is then introduced onto the rear of the body 202. The projecting lip 358 of the base 350 is introduced into the inlet 210 of the passage 204, whereupon the external thread 360 of the projecting lip 358 co-operates with the internal thread 214 in the first end 206 of the body 202. The base 350 can then be screwed onto the first end 206 of the body 202. Once the

base 350 is screwed in completely, its front face 352 abuts the first end 322 of the cover 320. This in turn axially locates the cover 320 against the ring 290, such that the base 350, cover 320, and ring 290 are all secured against one another. The body 202 is also secured to the base 350 by the threaded co-operation between the lip 358 and the first end 206 of the body 202. The body 202 therefore cannot move axially relative to the base 350, cover 320 or ring 290. The O-ring seal 355 ensures a sealing fit between the base 350 and the cover 320.

The nozzle gap 370 is checked using pin gauges or similar measuring instruments to determine whether it is the correct size. If not, the base 350 can be loosened and the adjusters 266 adjusted using an adjustment tool in order to ensure the correct size of the nozzle gap 370. Once adjustment has been completed, the cap 270 can be fixed to the front face 252 of the disc 250 using the plurality of threaded fixtures 278. Once the cap 270 is in place, the head of each adjuster 266 is located in a respective adjuster cavity 286 in the cap 270. As a result, the adjusters 266 cannot be accessed once the cap 270 is fixed in place.

Once the various components are secured together, a number of chambers and openings are defined between the various components. A first annular working fluid chamber 380 is defined by the annular channel 280 in the cap 270 and the front face 252 of the disc 250. The first working fluid chamber 380 communicates with both the outlet 212 of the passage 204 and each of the small passages 262 extending through the disc 250. A second annular working fluid chamber 390 is defined by the outer surface of the rearward projecting lip 298 of the ring 290, and the abutment face 332 and inner surface of the larger diameter section 330 of the cover 320. The second working fluid chamber 390 communicates with

both of the second supply passages 340 in the cover 320 and each of the small passages 306 extending through the ring 290.

A first annular transport fluid chamber 400 is defined by the outer surface of the body 202, the inner surface of the smaller diameter section 328 of the passage 326 in the cover 320, and the front face 352 of the base 350. The transport fluid chamber 400 communicates with both of the first supply passages 338 in the cover 320 and each of the secondary passages 230 extending longitudinally through the body 202. With the various components in position, the free space 242 forms part of a second annular transport fluid chamber 410 defined by the flange 222 and larger diameter section 228 of the body 202 and the inner surface 300 of the rearward projecting lip 298 of the ring 290. The second transport fluid chamber 410 communicates with each of the secondary passages 230 in the body 202 and the nozzle gap 370 defined between the disc 250 and the ring 290.

The manner in which the apparatus of the fourth embodiment operates will now be described, with particular reference to Figure 4. Initially, a first pressurised supply of working fluid (not shown) is connected to the inlet of the passage 356 in the base 350. The working fluid is preferably water. The working fluid passes through the passage 356 into the passage 204 of the body 202. From there, the working fluid exits the passage 204 via the outlet 212 and enters the first working fluid chamber 380. The working fluid leaves the working fluid chamber 380 via the small passages 262 and then passes into the first working fluid nozzle 263 defined between the channel 260 and the insert 261. The insert 261 is shaped so that the nozzle 263 has a smaller cross sectional area than that of the passage immediately upstream of the nozzle 263. As a result, the working fluid passing through the nozzle is accelerated as it exits the nozzle 263 into

the nozzle gap 370, creating a thin ring of working fluid exiting the nozzle 263.

At the same time as the first working fluid supply is connected to the passage 356 of the base 350, a second pressurised working fluid supply is connected to the second supply passages 340. Consequently, the second working fluid supply flows into the second working fluid chamber 390 via the second supply passages 340. From the second working fluid chamber 390, the working fluid passes through each of the small passages 306 in the ring 290. The second insert 308 and second channel 304 define the second working fluid nozzle 310 which receives working fluid from the small passages 306. As with the first insert 261, the second insert 308 is shaped so that the second working fluid nozzle 310 has a smaller cross sectional area than that of the passage immediately upstream of the nozzle 310. As a result, the working fluid passing through the second nozzle 310 is accelerated to form a thin ring of working fluid which enters the nozzle gap 370 substantially opposite the working fluid exiting the first working fluid nozzle 263.

As the first and second supplies of working fluid enter the apparatus 200, so does a supply of transport fluid. A transport fluid supply, preferably a pressurised gas, is connected to both of the first supply passages 338. Consequently, transport fluid enters the first transport fluid chamber 400. From there, it passes through each of the passages 230 in the body 202 before expanding into the second transport fluid chamber 410.

As can be clearly seen in Figure 4, the cross sectional area of the transport fluid chamber 410 is significantly greater than that of the nozzle gap 370 immediately downstream thereof, as defined between the disc 250 and the ring 290. As described above, as the nozzle gap 370

extends in the radial direction towards the circumference of the apparatus, its cross sectional area increases again. As a result, a throat section of reduced cross sectional area is defined in the nozzle gap 370 downstream of the second transport fluid chamber 410. As the transport fluid passes from the second chamber 410 into the nozzle gap 370, the reduced cross sectional area of the nozzle gap throat causes the transport fluid to undergo a significant acceleration. This acceleration causes the velocity of the transport fluid to significantly increase, possibly to a supersonic level. The high velocity transport fluid then comes into contact with the twin sprays of working fluid exiting the first and second working fluid nozzles 263,310.

As with the other embodiments described herein, an energy transfer takes place between the transport fluid and working fluid, primarily as a result of mass and momentum transfer between the high velocity transport fluid and the relatively low velocity working fluid. This energy transfer imparts a shearing force on the working fluid streams, leading to the atomisation of the working fluid streams. This atomisation leads to the creation of a dispersed droplet-vapour flow regime exiting the apparatus 200 over a 360 degree angle as a mist. As the nozzle gap 370 has diverging geometry, the transport fluid and atomised working fluid droplets accelerate as they pass along the nozzle gap. The diverging geometry of the nozzle gap 370 also means that the stream of mist droplets exiting the nozzle gap 370 itself diverges as it leaves the apparatus 200. This divergence of the mist droplets further improves the mist generation as it avoids the impinging and coalescing of the droplets into larger droplets as they leave the apparatus. Adjusting the nozzle gap adjusters 266 varies the relative positions of the disc 250 and the ring 290 and consequently the area ratio of the nozzle gap 370 defined between them. Adjustment of the nozzle gap in this way can vary the velocity and flow rate of the transport fluid,

and hence the degree of atomisation of the working fluid can also be varied accordingly.

As briefly discussed above, the diverging nature of the transport fluid nozzle gap offers improved atomisation over previous proposals. The transport fluid flow exiting the nozzle gap diverges, thereby reducing the likelihood of droplets impinging on one another and coalescing back into larger droplets.

The components of the fourth embodiment and their method of assembly also offer improvements in terms of working tolerances. Forming and assembling the components in the manner described above improves the accuracy of the relative axial and concentric positioning of the components. This ensures consistency of fit, particular with reference to the dimensions of the transport fluid passages and chambers.

Using a material having good machining properties, such as brass, for the first and second inserts ensures that the insert can be machined flush with the disc or ring without any burring problems which could partially or fully block the working fluid nozzles defined by the inserts. The inserts of the present invention maintain a clean edge when machined.

The preferred arrangement of the fourth embodiment provides working fluid nozzles which extend around the entire apparatus in order to provide a full 360° spray field from each nozzle. However, if such a complete spray field was not necessary or undesirable, the working fluid nozzles could be formed so that only certain angles of spray where achieved. This may be achieved by forming a plurality of circumferentially spaced holes in the ring and disc, respectively, in place of the full 360° nozzle illustrated herein.

The preferred location of the working fluid nozzles is approximately half way along the transport fluid nozzle gap in the radial direction. However, the working fluid nozzles may also be located upstream of the nozzle gap throat, at the throat itself, radially outwards of the throat, or else at the exit, or radial extremity, of the nozzle gap. Positioning the working fluid nozzles opposite one another in the nozzle gap leads to the working fluid sprays impinging on one another as they enter the nozzle gap. This further improves the atomisation mechanisms of the invention, but is not essential.

Whilst the illustrated fourth embodiment has first and second working fluid nozzles and associated supply passages, working fluid may also only be provided through one of the first and second working fluid nozzles. In such a case, the unused nozzle and passages can be left empty, or else the apparatus can be adapted to remove the redundant nozzle and passages.

Whilst the preferred transport fluid in the fourth embodiment is pressurised gas, steam may also be used instead.

These and other modifications and improvements can be made without departing from the scope of the present invention.

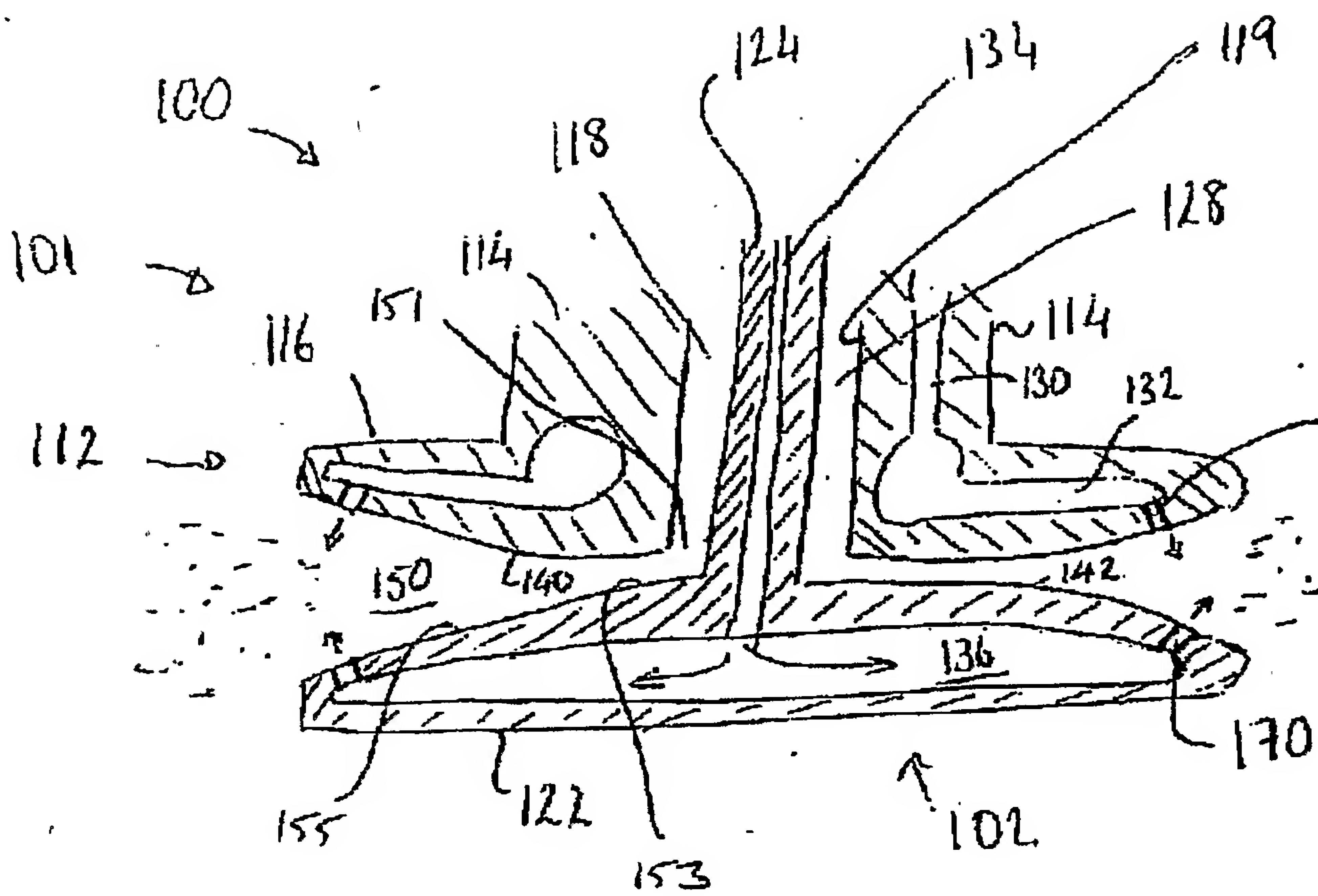
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Fig. 1

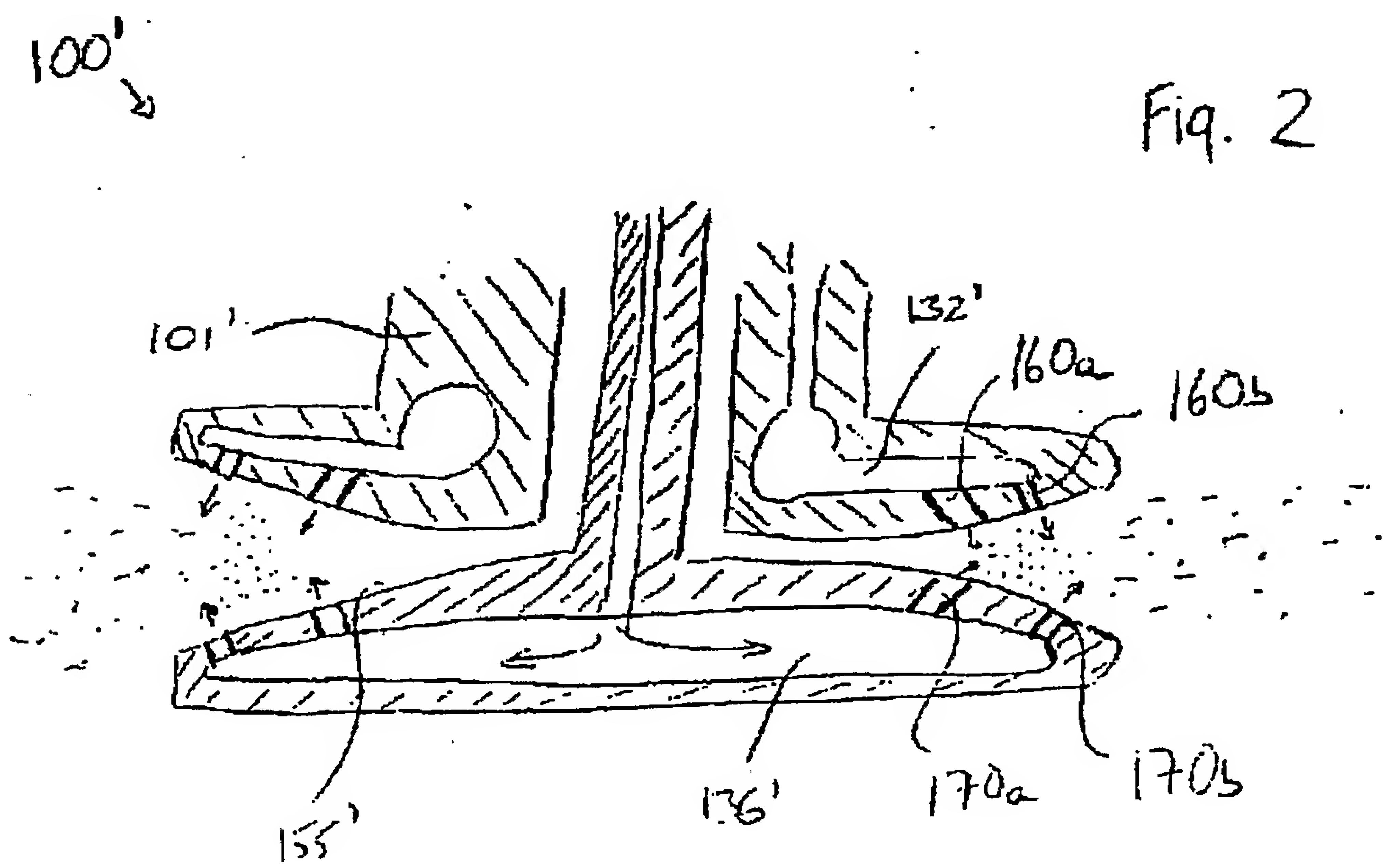
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Fig. 2

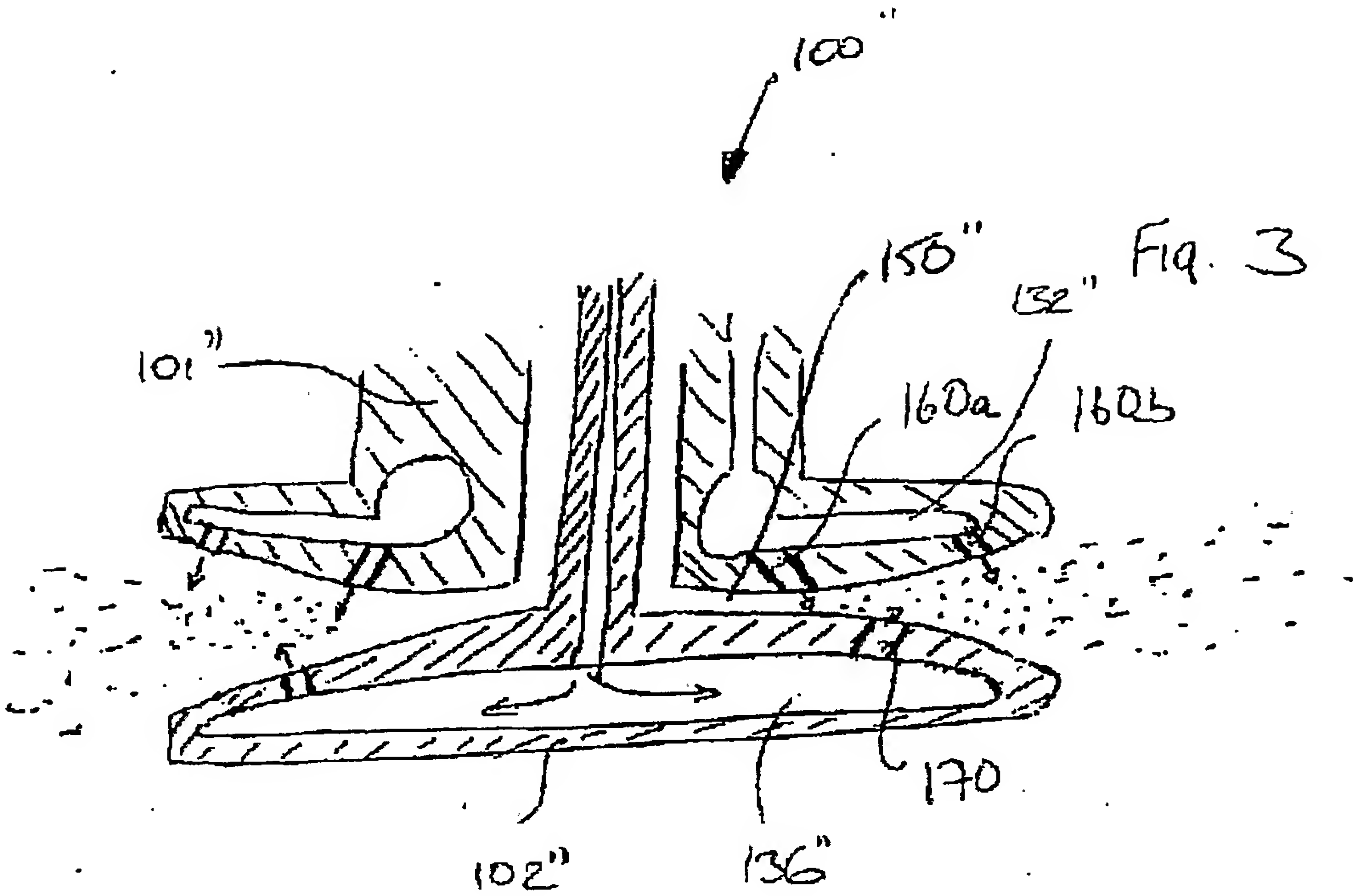

Fig. 3

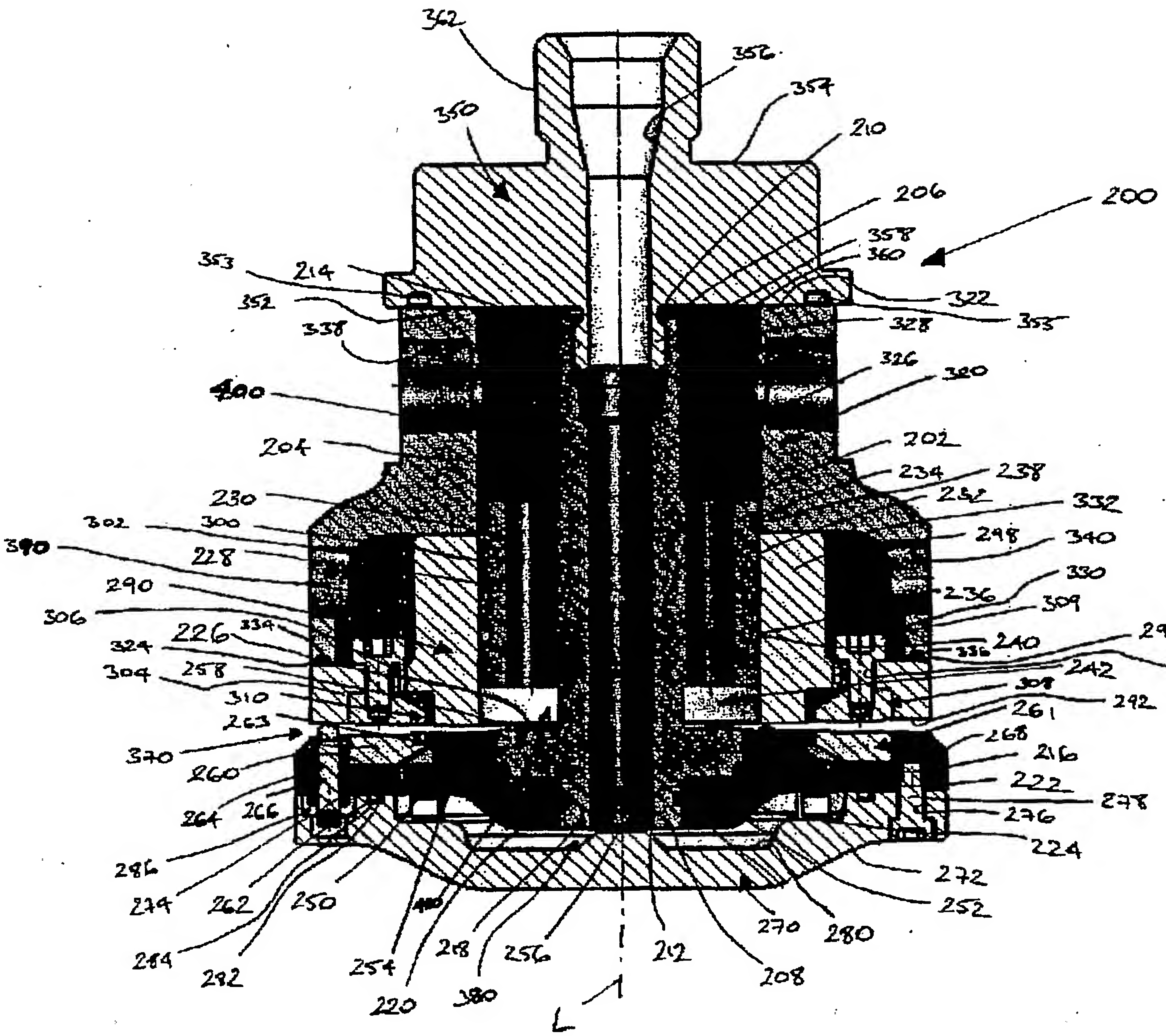

Figure 4

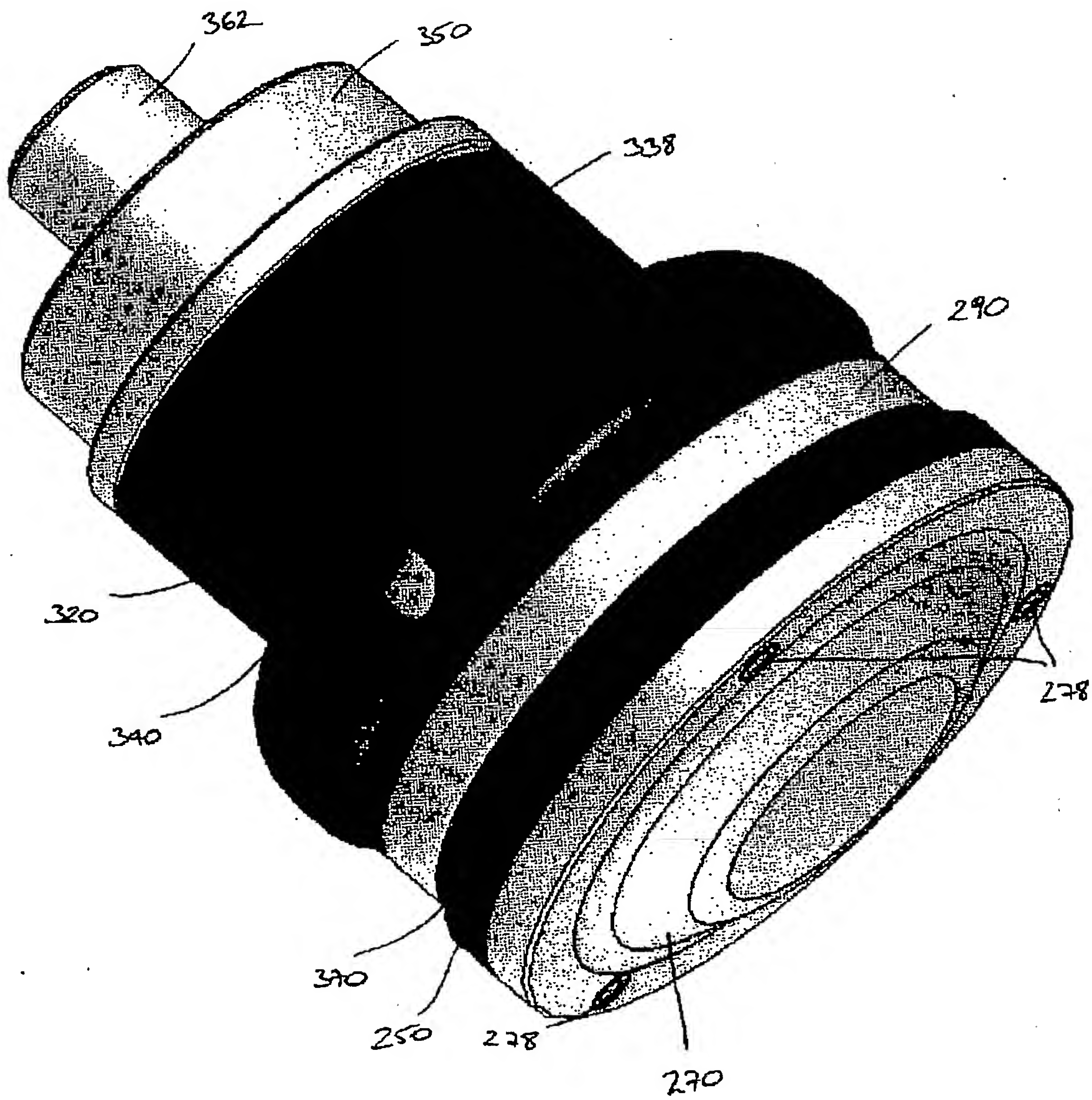

Figure 5